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Fleet aviators consistently rank situational awareness (SA) as a critical mission concern. SA, although elusive, must be understood and improved for the sake of mission effectiveness, expansion, survivability, and safety. The essence of SA is the reception, manipulation, and use of information. SA encompasses the physical, mental, psychological, social and physiological capabilities of the human operator. The operator must sense and perceive variables in the environment and then process that information. The information must be filtered and applied to the specific mission phase to maintain SA. Optimizing information formatting and presentation speeds, and meaningfully integrating data to display information elements or "chunks" that are readily useable to the aircrew can have a positive impact on aircrew SA. Rapidly developing improvements in information processing and transfer technologies, specifically sensor fusion and automation techniques, can provide even more diverse information to the aircrew. Efficient, effective presentation of necessary "information" to the aircrew is becoming even more important. By taking a closer look at sensor data and investigating advanced technologies, we can present a more comprehensive, focused "picture" of the environment to the aircrew; enhancing SA. This process, logically, will result in increased threat awareness/avoidance, increased mission effectiveness, improved survivability, and increased safety.

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SITUATIONAL AWARENESS: WHAT IS IT? CAN IT BE IMPROVED?

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ABSTRACT

Fleet aviators consistently rank situational awareness (SA) as a critical mission concern. SA, although elusive, must be understood and improved for the sake of mission effectiveness, expansion, survivability, and safety. The essence of SA is the reception, manipulation, and use of information. SA encompasses the physical, mental, psychological, social, and physiological capabilities of the human operator. The operator must sense and perceive variables in the environment and then process that information. The information must be filtered and applied to the specific mission phase to maintain SA. Optimizing information formatting and presentation speeds, and meaningfully integrating data to display information elements or "chunks" that are readily useable to the aircrew can have a positive impact on aircrew SA. Rapidly developing improvements in information processing and transfer technologies, specifically sensor fusion and automation techniques, can provide even more diverse information to the aircrew. Efficient, effective presentation of necessary "information" to the aircrew is becoming even more important. By taking a closer look at sensor data and investigating advanced technologies, we can present a more comprehensive, focused "picture" of the environment to the aircrew; enhancing SA. This process, logically, will result in increased threat awareness/avoidance, increased mission effectiveness, improved survivability, and increased safety.

Seeing the term situational awareness (SA) on lists of concerns generated by operator advisory groups, aircrew system advisory panels, and various working groups prompted us to explore the meaning of the term SA to better understand it and do something to improve it. Querying aircrew and con-

ducting research, we discovered more definitions of SA than are possible to print in the limited space of this paper. There was, however, one definition that encompassed them all: "Knowing what's going on so you can figure out what to do!"[1]

Looking at SA from the tactical viewpoint, we should be aware that three worlds exist: First, the actual physical environment - unalterable, finite in scope, from which air-crew, aircraft systems, and sensors draw data and information. Second, a world model exists within the aircraft - its systems and displays. This world consists of data gathered by aircraft systems, transformed into information (correct, erroneous, or misleading) and presented to the aircrew. Third, a world model exists in the aircrew's mind - the summation of training, experience, motivation, comprehension, and intelligence. The reconciliation of these three worlds is at the root of SA.

Improving tactical SA is complicated by advances in sensor technology (more information is becoming available to the aircrew) and by the proliferation of sophisticated threats emerging from nonaligned and third-world countries (the former Soviet Union sells offensive and defensive weapons systems to the highest bidder). Additionally, third party modifications to these weapons systems creates instability in their operating parameters, making accurate and timely intelligence gathering extremely difficult. These factors, combined with austere budgets and long lead times to develop adequate countermeasures, electronic attack and protection systems require innovative, resourceful, and timely solutions to the SA dilemma - how to transform available data into meaningful, accurate, and timely information for the aircrew.

Specific components that should be included in a comprehensive definition of SA are: "(1) extracting information from the environment; (2) integrating this information with relevant internal human knowledge to create a mental picture of the current situation, (3) using this picture to direct further exploration in a continual perceptual cycle, as well as to (4) anticipate future events."[2] The following are some cost effective improvements in information transfer to the aircrew. We have spent the last year developing guidelines for improving SA by simply improving the design of

data-to-information processing and the display of this information to the crew. Although the improvement of SA is a complex issue, these advances in hardware and software can be implemented immediately to improve tactical combat aircrew performance.

Improved Head-up Display (HUD) and light-weight, multi-image source Helmet-Mounted Display (HMD) technology, increased resolution and size of color flat panel head-down displays, and the added dimension of color information coding will ultimately improve the value of visual information passed to the crew. More efficient ways of representing information, including symbols, visual and audio icons, unique data formats, three dimensional (3D) audio, etc., will improve information transfer. We are exploring ways of information formatting, combining/separating, and more logically integrating information before presenting it to the aircrew. The intent is to improve the presentation of multiple data "chunks" in a more natural format.

Individual aircrew receive and use information differently to achieve and maintain SA. These differences are significant, both between and within aircrew. Between, due to the various capabilities and limitations within the population; within, due to dynamic state changes constantly occurring within the individual, such as stress, fatigue, physical and psychological well-being, G forces, etc. These differences have not been adequately addressed in the data-to-information flow of current weapon systems. Improving the information transfer between systems and the aircrew who must control and use them is a high payoff area for SA improvement.

Sensor and processing capabilities are overloading the aircrew with data. For example, detection of an airborne emitter, on a bearing, are data. Until the aircrew know more about the platform carrying the emitter, and its intent, SA is incomplete. To prevent data flow induced degradation of SA, we must transform the enormous stream of data into crew-useable information. Attempting to fully exploit a tactical aircraft's systems can overwhelm the operator's ability to convert data-to-information-to-adaptive response. The job of crew-systems engineers is to convert these data to information and to present the information to aircrew in formats and at rates they can handle.

The following are some examples of enhancing SA through cognitively friendly and intuitive interface design. These examples hold the promise of passing more tactical and navigation information quickly and intuitively.

- Vector Product Format (VPF) map features are points, lines, or areas defined by polygons. The map features and content are preserved at any magnification and the map also maintains maximum digitized positional accuracy. Aircrew can display a vector data file at any scale and selectively suppress designated features. VPF maps can be customized for mission-specific requirements. While raster format requires more storage space, vector files take longer for data access and display. The payoff is in the flexibility and versatility of VPF.

- Other independent map features include Frame of Reference, that is, whether the map is presented "north-up" or "track-up." The north-up alignment provides a fixed frame of reference, but tends to require more mental transformations for the aircrew to remain oriented. The track-up alignment may require fewer and simpler mental transformations, but has an unstable frame of reference during aircraft flight maneuvers. Therefore, for tasks that involve navigating or maintaining a prescribed flight path, a track-up alignment supports better performance while tasks that involve reconnaissance, or orientation with regard to waypoints, a north-up alignment enhances performance. It seems logical that a pilot-selectable alignment is necessary.[3]

- 3D perspective view display presentations have received a lot of recent attention. Although real time 3D displays require computer-intensive processing, some researchers think that a 3D display will provide a more natural representation of the aircrew view than a 2D display. A single 3D display that integrates information from several sources will reduce the need to mentally integrate these sources of information during a mission, thereby reducing the cognitive load imposed on the aircrew. Conversely, some research shows that the realism of a 3D scene may detract from a mission because the depth cues may not be accurate, there's more clutter, and convergence of various dimensions into one object may cause distortion, therefore the use of 2D and 3D presentations may be task dependent. Research indicates

that 3D presentations improve accuracy for conflict avoidance maneuvers, detecting threats, and result in faster response times for lateral and altitude tracking judgments. 2D displays can support more accurate flight control.[3]

- Offboard sensors, combined with communications, cockpit displays, sensor integration techniques, and mission support systems will enhance mission effectiveness and survivability beyond that achievable with onboard sensors alone. The integration of onboard and offboard sensor information will either enhance SA and result in improved mission performance or completely overwhelm the aircrew resulting in burdening workload and degraded SA. There are many avionics issues, and of course, timeliness plays a major role in data usefulness. But, presenting sensor information from multiple sources so that aircrew readily understand the implications of the information and can take immediate action as it pertains to their mission is a real challenge.

- Pictorial displays are being explored as a solution to the complexity of modern aircraft and missions. Crew-in-the-loop studies were conducted to evaluate the utility and crew acceptance of pictorial format displays for two-seat fighter/attack aircraft. The evaluation also explored whether utility and crew acceptance were affected by the application of color, and to recommend format changes based on the results. Crews clearly supported the concept of pictorial formats and preferred the color version.[4]

- Under the High-Angle-of-Attack Technology Program (HATP), two integrated pictorial displays were developed for simulation evaluations and flight test onboard the F/A-18 High Alpha Research Vehicle (HARV). The first concept is a nosepointing display illustrating the range of control the pilot has over the aircraft nose. The second concept is a predictive flightpath display that allows the pilot to see how current control inputs will affect aircraft future position and orientation. These display concepts were viewed in a wide-field-of-view HMD while engaged in an air-combat simulation.[5]

- 3D auditory technology refers to the manipulation of a sound signal to give the user the illusion that the sound emanates from a particular location in space. Because aircrew operate in an environment where spatial cues are im-

portant, 3D audio has the potential to provide aircrew with sounds that are either separated in space or allocated to a specific location. Additionally, the development of vertically localizable auditory cues may be useful for enhancing the spatial orientation of pilots in aircraft who are visually loaded and fail to maintain instrument scans.[6]

Our approach to SA improvement involves systematically applying viable techniques to our crew-centered approach. We use an iterative process of research, select, test, modify, retest, and accept before recommending improvement initiatives. In-house rapid prototyping and simulation at Patuxent River allows us to quickly evaluate concepts and record performance.

Using this approach, viable research, and lessons learned from previous programs, we developed guidelines that can be included in performance-based specifications during product acquisition. The guidelines are simple, logical, and easy for designers to apply in selecting and formatting information processors and displays. The guidelines carry forward already validated formats and principles. Bear in mind that presentation of information to the aircrew is only one part of improving SA, however, it is a part that is relatively affordable, can be achieved through evolution, and can be easily tested to determine performance results.

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